Summary of the AIRS Science Meeting 22-24 October 1997
Lockheed Martin, 2 Forbes Road, Lexington, Mass

Project and Program Status

Mous Chahine, AIRS Science Team leader, summarized the status of EOS PM and AIRS projects. The launch date of EOS PM is still December 2000. The spacecraft, built by TRW in Redondo Beach, CA, is the first of a series of common spacecraft for NASA and NOAA polar orbiting missions. Points of particular interest to the team are:

1. It is likely that the way the EOS PM data will be processed will change from processing at the DACC to PI mode processing, i.e. the team leader facility is given the task (and funding) to do the AIRS/AMSU/HSB operational processing, The DAAC at GSFC will strictly be the data archiving and distribution center. This will have no direct impact on the team members.
2. The AIRS science and data processing budget has been cut by 20% in December 1996, followed by an additional cut of 10% in May 1997 for FY98, with somewhat lesser cuts in the following years. Some science team member budgets for FY98 will be impacted.
3. In view of the buildup for IMAS, AIRS/IMAS at JPL has been elevated to program status.
   Fred O'Callaghan is now the AIRS/IMAS program manager, Avi Karnik is the AIRS project manager, and Tom Livermore is the IMAS project manager.

Fred O'Callaghan (*) presented the AIRS Project Status.

a) The AIRS EM (engineering model) cryo-dewar testing, i.e. the AIRS EM focal plane in the dewar, cooled by the mechanical cooler, has been completed. The dewar, and the cryo-cooler functioned as expected. The detector data are under evaluation.
b) The EM spectrometer build is almost completed. All components have been installed, warm alignment and focus tests have been passed successfully. The optical performance equals or exceeds specifications.
c) The testing of the EM using the ATCF is scheduled to be completed by December 1997.
d) Most of the material for the FM (flight model) is in house. The instrument delivery is scheduled for December 1998.
e) The TRW spacecraft design is well under way. AIRS successfully played the role of a pathfinder for the spacecraft interfaces.
f) Three issues and concerns :
   1. A decision has to be made on ruling an additional grating for the FM to tune the blaze angle. The currently available grating blaze angle is 16.4 degree. 16.0 degree would be optimum.
   2. Grows of additional detector material for bands M3, M9 and M10 is in progress.
   3. Given the experience of MODIS with the Denton overcoat of the scan mirror, AIRS is re-evaluating the use of Denton coating on the AIRS scan mirror.

2. Hardware status update

Paul Morse (*) presented the AIRS Instrument Development Status.

1. The program technical focus is now on the EM and FM build and test. It is a schedule driven environment focused on completing the EM by October 1997 and delivery of the FM (September 1998). The design is essentially complete. The EM build is nearing completion. Early test results are encouraging. The M12 (14.67-15.4 micron) array has a median NEDT=0.4K with zero outages. Required for the FM is NEDT=0.35K or better, with less than 2% outage. Outage is defined as any detector a factor of 2 or more worse than the required NEDT. The build of the FM is paced by the IR focal plane build and test.
2. Progress with the engineering model has been substantial. The cooler/focal plane have been successfully integrated and tested. This was a major step. The spectrometer assembly, alignment and wave-front testing is almost completed. The wave-front error, using a 3.39 micron laser, tests the performance of the spectrometer from the entrance aperture to a retro-reflector mounted on the focal plane. Wave-front tests with the spectrometer at 300K show excellent optical quality: 0.86 wavelength error (p-v) at 3.39microns. Wave-front testing with the spectrometer at 150K and the focal plane at 58K are the next major steps.
3. The AIRS Test and Calibration Facility (ATCF) build is complete and in the final checkout phase. The ATCF has spatial, spectral and radiometric measurement capability. The Ground support data acquisition station and processing software development is almost complete. The data acquisition hardware and processing software demonstrated its capability in support of the cold engineering dewar testing.
4. An AIRS focal plane system scorecards format has been developed. For each of the 12 focal plane arrays the scorecard shows the projected system NEDT (noise equivalent temperature difference) and percent array outage for the available array modules. Flight and flight backups have been identified for M11 (M11-006, with NEDT=0.15K median and 2% outage) and M12 (M12-004, with NEDT=0.26K median, and zero percent outage). The NEDT performance on other arrays is typically a factor two better than required, but no flight arrays have been identified due to excessive outage and or read-out-electronics (ROIC) liens.
5. Two EM gratings and a potential flight grating (PFM-01) have been ruled. The PFM-01 grating has two liens: the blaze angle is slightly high, 16.4 degree, compared to the ideal 16.0 degree, and there is a blaze angle variation of +/- 0.4 degree across the grating surface. The first lien causes a small decrease in the efficiency at the array edge at the shorted wavelengths, particularly between 3.91 and 3.98 microns. The need for ruling a replacement grating is being evaluated. Analysis indicates that the blaze angle non-uniformity causes a degradation in the Cij, but has minimal impact on the 4.2 and 15 micron sounding regions.

Bjorn Lambrigtsen (*) provided an update on the status of the AMSU and the HSB. The NASA AMSU model is now being built. Antenna testing has been completed: Excellent results. A delay in the DRO delivery from Litton Industries has used up the schedule reserve. Projected delivery is now October 1998. The HSB parts are being manufactured and subsystems are in the assembly phase. Matra Marconi Systems is proceeding on schedule. Concerns are the antenna RF boresight testing and the EOS thermal environment. The planned optical boresight measurement can not meet the RF boresight knowledge requirement.

Data Processing and Instrument Operations (DPIO)

Denis Elliott (*) presented the status of DPIO.

1. DPIO is working on Science Data Processing System (SDPS) Prototype 6. The functionality improvement of SDPS Prototype 6 over Prototype 5 include: use of a PCF (process control file) for opening Level 0 data files; calibration smoothing across data granule boundaries; initial implementation of DC Restore correction; integration of 100-layer rapid transmission algorithm into team algorithm.
2. Prototype 7 will be the beta delivery to the DACC. It will include the following additional functional improvements: full DAAC compatibility (toolkit for I/O and status messages, ESDT's, metadata); greatly reduced number of output files and use of HDF Swath format; update of radiometric calibration for all instruments; AIRS spectral calibration; re-integration of initial cloud clearing and initial retrieval code from NOAA.
3. An overview of the Instrument Operations Support activities over the past year was given. Highlights include: AIRS flight software developments; PM spacecraft software interactions; obtaining an AIRS version of the Flight Operations Segment software.

Sung-Yung Lee (*) presented the status of the Level 2 software at the TLSCF:

1. The 100 level rapid algorithm was incorporated into the Prototype 6 software.
2. A new version of the two layer cloudy data sets was generated to compare 66 level and 100 level results for nadir footprints.
3. Training data sets for the new data sets were generated and can be downloaded from the TLSFC (xi.jpl.nasa.gov).
4. A software patch to the 100 level RTA was made to take account of the thin layer at the surface.
5. Team algorithm statistics were presented based on 66 level and 100 level RTA. The current simulations do not include simulation of the Cij (measurement simultaneity) effects.

Calibration

George Aumann (*) distributed a review copy of the AIRS Instrument Calibration Plan, currently also available on the AIRS home page (www-airs.jpl.nasa.gov).

The calibration plan gives an overview of the spectral, radiometric and spatial calibration of AIRS, hardware tools (such as the ATCF), software tools, predicted calibration accuracies and assumptions. The EM testing will serve to validate the tools and the assumptions. The tight schedule of the EM testing is a concern. The plan for the calibration of the flight model includes two end-to-end tests: A spectral calibration test using a 6 meter gas cell, and a radiometric test, where the AIRS (mounted in the ATCF) looks upward through a flat folding mirror into a vertical air column. The tools available for AIRS calibration are adequate to meet the FRD specified calibration accuracies.

Access by science team members to the data produced during the EM testing and the flight model calibration will be via the TLSCF at JPL. The data access serves as an interface test model for data access during flight for level 1b and level 2 data product validation.

Wallace McMillin (*) presented details of the data simulations done in preparation for the "end-to-end spectral calibration verification" using gas cell measurements for CO_2 in the 650-685 cm-1 region. The transmission of the gas cell, about 6.6 meter long and filled with 2 torr of CO_2 at ambient temperature, is about 20% at 667 ccm-1. Assuming reasonable errors for the spectroscopy, an error of the order of 0.5% in the AIRS SRF width is detectable. The method is sensitive to deviations of 30% in the SRF wing response 1.5 FWHM from the SRF centroid. Similar results were found in preliminary simulations for H_2O in the 1460-1525 cm-1 region.

Paul Van Delst (*) presented details of the preflight validation of AIRS using the AERI. The AERI is an uplooking interferometer, which covers the same wavelength region as AIRS. Spectral resolution is somewhat higher than AIRS, and the radiometric calibration accuracy at 300K is about 0.2K. AERI comparisons at DOE ARM CART site IOP's (in 1995, 1996 and 1997) with other instruments and calculations relative to radio sondes have shown excellent agreement. The comparison of the AIRS uplooking test data with simultaneously obtained AERI data complements the AIRS gas cell measurements: For the gas cell the source temperature is about 310K and the gas is seen in transmission, while for the uplooking test the source is the cold sky and the atmospheric gases are seen in emission. Simulations of clear sky radiance residual comparisons indicate that in the atmospheric windows near spectral lines a 1% error in the claimed AIRS FWHM can be identified using the AERI as a reference spectrometer.

Retrieval Algorithm Progress

Joel Susskind (*) discussed three areas where progress has been made since the last team meeting:

1. Preliminary evaluation of the 100 level test data and upgrades to the JPL prototype system. Results from the 100-level test cases show consistency with the corresponding 66-level test cases, except for some slight degradations which are attributed to the additional complexities introduced by the more realistic physics. The results for both cloud clearing and retrievals are improved significantly in the two-formation cases, and are similar to previous results in the one-formation cases.
2. The Team Algorithm code on the TLSCF computer at JPL has been updated. This month, a partial second pass was added, and channels highly sensitive to water vapor were included in the second temperature sounding pass. In addition, microwave channels were added to the surface retrieval
3. In order to cloud-clear using the nine footprint centered on the AMSU, all footprints have to be normalized to the same slant path. Measurements (at any given wavelength) are considered equal if they agree in radiance within 3 * NEDeltaT. The 1.1 degree slant path correction is significant compared to the measurement noise. A regression approach to calculating the angle correction seems appropriate.

<u>Action Items:</u>

Larry McMillin will define the regression approach and estimate resource requirements to implement it.

Sung Yung Lee: Until the regression approach correction is implemented simulate only the 30 AMSU slant angles.

Chris Barnet (*) described an improved approach to handle clouds. The improved approach is analogous to the old approach, but uses the 9 spots (3 x 3 AIRS footprints centered on an AMSU footprint) for up to eight cloud formations. This involves a more generalized implementation of the determination of the cloud clearing extrapolation vector eta, starting from the nine individual AIRS spots rather than from groups of three spots. He found improved discrimination between one and two cloud formations, as well as the capability to solve for three or four cloud formations. The results for both cloud clearing and retrievals are improved significantly in the two-formation cases, and are similar to previous results in the one-formation cases.

Larry McMillin (*) presented details of his effort to reduce the error in cloud clearing for the upper troposheric channels. The approach was to use eigenvectors of the cloud effects in the cloud clearing. This naturally averages the spots for the higher peaking channels and does cloud clearing for the lower peaking channels. The result was that the errors for the higher peaking channels were reduced, but the errors for the lower channels affected by clouds was increased. Because of the increase in the lower channels, the approach was abandoned.

Mitch Goldberg (*) presented progress in three areas:

1. The comparison of retrieval errors based on the old 66 level fast RT model and the new 100 level fast RT model. Temperature errors are very similar, but water vapor retrieval errors increased by about 5% between 200 and 850 mbar.

2. Coefficients for the First Product Algorithm have been generated and will be provided to the TLSCF at JPL.

3. It may be desirable to represent AIRS level 1b radiance using an eigenvector compression: a) to distribute the data in a compressed form and b) to use the statistics of the fit (the number of eigenvector needed to fit the data to within the noise) is potentially a powerful quality control tool. Based on eigenvector reconstruction of radiances of the HIS CAMEX 1 flights and the identification of previously unnoticed systematic errors in the HIS spectra, the potential of this method as quality control tool is confirmed. At this point is not clear if AIRS data for all sky conditions can be compressed as a means of providing data to users with less volume.

Forward Algorithm Progress

Larrabee Strow (*) discussed improvements to the fast forward algorithm, including accounting for the reflected thermal radiation and variable CO2 concentrations. The reflected thermal radiance is computed using 5 predictions to an accuracy of better than 0.1K with little impact on the computing time. Variations in the CO2 concentration (1% annual variability and a 0.5%/year upward trend) are handled as offsets to the existing fast transmittance calculations. Accuracies are better than the AIRS noise with several easily computed predictors.

Dave Tobin (*) described the use of AERI radiance measurements for development and validation of the AIRS forward model. Two conclusions are:
1) Bob Toth's recent measurements of 10 H2 16O spectral line widths improve agreement with observations for many lines.
2) The 10 micron self-broadened water vapor continuum can be derived partially from AERI spectra, if the atmosphere (column) is well characterized.

Phil Rosenkranz (*) provided details on the AMSU-A and AMSU-B transmittance coefficients recently delivered to JPL. The coefficients were computed from a revised model for the water vapor continuum. The revised model is based on a re-analysis of laboratory measurements. It combines the foreign-broadened continuum component of MPM87 and the self-broadened continuum component of MPM93. (The current AIRS-AMSU simulations use the older, MPM87 model for both components.)

Michael Schwartz discussed transmittance calculations based on measurements in the 52.8 - 55.5GHz region (AMSU channels 4-7) using the MTS on the ER2 during CAMEX I flights. There were some calibration problems. Better measurements will soon be available using the NAST.

Mark Hofstadter (*) pointed out the need to improve the AIRS data simulation for the development of research products and analysis of flight data. Current forward models used in the visible, the infrared and the microwave make different assumptions in their treatment of transmissive clouds, cloud overlap, cloud microphysics, cloud vertical structure and scale of horizontal variability. The level 2 truth files need to be modified to include this additional cloud information, which the forward algorithm must use.

Action Item:

Hofstadter: Define modifications to the level 2 truth file which include the additional cloud parameters and distribute then for review to the team members. Consensus to be obtained at the February 1998 team meeting.

Validation

Bob Haskins (*) described the AIRS Post-Launch Algorithm Development and Validation Concept. He proposed to archive four 1-week global data sets of AIRS L1a data during the first year for algorithm testing and development. For diagnostic spot checking of the results produced by the operational processing at the DAAC one orbit/week would be processed at the TLSCF.

Eric Fetzer (*) described the approach and the goals of the validation effort at the TLSCF at JPL. Key assumptions are outlined in the white paper entitled "AIRS Validation Facility Software Requirements". The intent of the effort is build a system that:

a) meets the primary needs of the retrieval algorithm developers
b) makes important validation data readily accessible,
c) uses commercially available software
d) extends software lifetime with object oriented programming.

George Aumann (*) discussed the AIRS In-Orbit Checkout. Stages of increasing instrument stability and instrument characterization improvements are matched to stages of software complexity. Key milestones are the in-orbit instrument performance review at launch+12 weeks, when the level 1b data are validated, and the operational readiness review at Launch + 30 weeks. At launch +32 weeks the AIRS level 2 data output from the EOC are validated. Each team member needs to start focusing on specific tasks within the checkout period.

Hank Revercomb (*) summarized the observations and findings from the second special observing period held 15 September - 5 October 1997 at the DOE Radiation Measurement Program in Oklahoma in presentation entitled "Atmospheric State for AIRS Validation: Preliminary Messages from the 1997 ARM Water Vapor IOP. The observation inter-compare a wide range of measurements based on different absolute standards, including chilled mirror/frost point hygrometers at 60m, 30m heights and at ground level, on tethered balloons and on kite platforms below 1 km height, and on aircraft up to 13 km. Continuous observations of total precipitable water were made by microwave radiometers, sun photometers and GPS. Profiles of water vapor and temperature were made by Raman Lidar, AERI and RASS. The findings are important for understanding the accuracy of the atmospheric state for AIRS validation.

Bill Smith (*) discussed CAMEX 3 (Convection and Atmospheric Moisture Experiment) and its relevance to the AIRS program for the validation of forward and inverse algorithms in the tropical environment. CAMEX 3 is scheduled for August - September 1998 with flights from Florida. On the NASA ER2 will be the MODIS Airborne Simulator (MAS), the Microwave Imaging Radiometer (MIR, with 54, 118 and 183GHz channels similar to AMSU-A and AMSU-B and IMAS) and the IR Interferometer sounder (4-15 micron with resolution u/du > 1000), with the cross-track scanning capability. LIDAR, up-looking FTS (AERI) and DIAL system will be used to characterize the vertical column water vapor column with better than 1km resolution and 5% accuracy.

Allen Huang (*) demonstrated the concept of prelaunch validation of the AIRS cloud cleared radiances using MAS and HIS measurements from the ER2. Cloud clear HIS radiances derived from different size fields of view (4km, 8 km and 16 km using the N* method) were compared with MAS averaged clear pixels, i.e. identified by the MAS cloud mask algorithm as clear with 99% confidence. Surface, water vapor and cloud gradient effects on the accuracy of the cloud cleared radiances are considered to be significant.

Catherine Gautier (*) presented a forward model including cloud scattering for the AIRS visible/near infrared and infrared spectrometer channels. The goal of this effort is to improve the accuracy of the cloud height detection algorithm for low altitude clouds, by combining infrared and visible observations. Discrimination of low clouds is important for the AIRS level 2 data product validation in coastal areas.

Research Reports

Bob Haskins presented a talk on "Radiance Variability and Climate Models" using 1971 data from the IRIS (Infrared Interferometer System on Nimbus). Spectral empirical orthogonal functions (EOFs) derived from the covariance of satellite radiance spectra may be interpreted in terms of the vertical distribution of the covariance of temperature, water vapor, and clouds. Important constraints that are resolved using spectral radiances can be placed upon climate models, enabling AIRS data to be useful to study model processes within one year after launch.